NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

407 733

THE Marquardt CORPORATION

15 JUNE 1963

REPORT PR 281-4Q-4

COPY NO. 19

(Title -- Unclassified)

TENSILE AND CREEP-RUPTURE PROPERTIES OF DISILICIDE-COATED UNALLOYED MOLYBDENUM SHEET AT 2800°, 3000°, AND 3200°F

DDC
RECEIVED
JUN 25 1963
TISIA B

UNCLASSIFIED

(Title -- Unclassified)
TENSILE AND CREEP-RUPTURE PROPERTIES OF DISILICIDE-COATED UNALLOYED MOLYBDENUM SHEET AT 2800°, 3000°, AND 3200° F

Contract AF 33(657)-8706

Project 281

PREPARED BY

A S Rabenstiene
A. S. Rabensteine

APPROVED BY

M. J. Albom, Manager
Materials and Process Section

CHECKED BY

J W Chambers
J. W. Chambers
Project Engineer

UNCLASSIFIED

THE Marquardt CORPORATION
VAN NUYS, CALIFORNIA

MAC A719B

CONTENTS

TABLES

ILLUSTRATIONS

I. SUMMARY

Tensile and creep-rupture properties were obtained for disilicide-coated unalloyed molybdenum sheet (0.040 inch) at 2800°, 3000°, and 3200°F. The base metal substrate was disilicide coated approximately 0.0025-inch thick. A two-color Shawmeter (optical pyrometer) provided an accurate and convenient method to determine and to control test temperatures on the coated specimens. The ultimate tensile strengths at 2800°, 3000°, and 3200°F were approximately 12, 11, and 10 Ksi, respectively. The stress values to cause 2 percent creep in 2 hours at 2800°, 3000°, and 3200°F were 4.3, 3.8, and 3.0 Ksi.

II. INTRODUCTION

In aerospace applications, almost all refractory metal usage is in an oxidizing environment. One of the most widely used refractory metals is commercially pure molybdenum, and the coating system that has found the greatest favor for protection against oxidation is the disilicide coating.

The mechanical properties of commercially pure molybdenum have been well documented. However, as the disilicide coating is a diffusion type, the effect of such a protective system on the mechanical properties of the bare metal is of great importance.

The program reported herein was conducted to determine the tensile and creep-rupture properties of disilicide-coated unalloyed molybdenum sheet (0.040 inch) at 2800°, 3000°, and 3200°F.

III. TEST PROCEDURES

A. Preparation of Test Specimens

Tensile and creep-rupture test specimens were prepared from 0.040-inch thick unalloyed molybdenum (AMS 7800). A finish of 32 rms or better was given to all surfaces. Special consideration was given to the edge radius in the reduced section of the specimens. The specimens were lightly vapor-honed, degreased, and then disilicide coated approximately 0.0025 inch thick. After coating, the specimens were oxidation tested in air at 2500°F for five minutes. None of the specimens failed in this test.

B. Test Equipment

Tests were conducted on the Marquardt Elevated Temperature Test Machine (Figure 1) in a still air atmosphere. Specimens were self-resistance-heated to test temperature and held at temperature for five minutes prior to loading. Strain rates were controlled using a calibrated load cell. A Marquardt-developed electromechanical extensometer was used for strain measurement. Dead weight loading was used during the creep tests.

C. Temperature Measurement

A two-color Shawmeter (optical pyrometer) was used to measure test temperatures. The Shawmeter was calibrated against a special battery-operated calibration unit using a standard tungsten filament calibration lamp (G.E.) before each test, and at approximately one-hour intervals during the creep tests.

IV. TEST RESULTS

Tensile properties of disilicide-coated unalloyed molybdenum sheet obtained at test temperatures of 2800°, 3000°, and 3200°F are presented in Table I. Creep-rupture properties obtained at 2800°, 3000°, and 3200°F are presented in Table II. These data are shown graphically in Figures 2 through 6.

The ultimate tensile strengths at 2800°, 3000°, and 3200°F were approximately 12, 11, and 10 Ksi, respectively. Yield strengths were approximately 8, 7, and 6 Ksi. The stress values to cause rupture in 2 hours at 2800°, 3000°, and 3200°F were 4.17, 3.7, and 3.15 Ksi, respectively. The stress values to cause 2 percent creep in 2 hours were 4.3, 3.8, and 3.0 Ksi.

V. DISCUSSION

Tensile and creep-rupture testing of the disilicide-coated molybdenum presented special problems in the area of high temperature measurement. With uncoated specimens, temperature can be measured up to 5000°F in an inert atmosphere by the use of thermocouples. However, thermocouples cannot be directly welded to a coated specimen (as is the procedure for testing specimens of bare metal.)

The Shawmeter was utilized in this program because it is not dependent on known emittance values of the disilicide coating as is required in the use of the Micro-Optical Pyrometer (one-color pyrometer). The exact emittance of the coated molybdenum was unknown, and the emittance varied with time at the elevated test temperature investigated.

Prior to tensile and creep-rupture testing, the following steps were taken to improve the Shawmeter technique:

1. The addition of a meter to allow incident energy input to be adjusted to the same value for all test and calibration readings.

2. A table of tungsten calibration lamp and color temperatures was programmed for IBM and run off to obtain a compilation of brightness, color, and contrast values at 1° intervals over the test temperature range.

3. A special battery-operated calibration unit utilizing a standard tungsten filament calibration lamp (G.E.) was used to calibrate the Shawmeter.

4. The Shawmeter was calibrated at one-hour intervals during the test runs. The maximum drift in one hour was no more than ±20°F.

5. During test runs, the Shawmeter was positioned far enough away from the heated test specimen to insure that the viewing window did not become coated.

VI. CONCLUSIONS

The scatter of both the tensile and creep data was quite small, indicating that the raw material properties were uniform. In addition, the coating process was reproducible, and temperature control was uniform.

The Shawmeter was capable of accurate temperature measurements on the disilicide-coated molybdenum specimens within ±50° at 3200°F.

The optical pyrometer cannot be used on coatings for long periods of time unless the effect of time on the coating's emissivity is known.

TABLE I

TENSILE PROPERTIES OF DISILICIDE-COATED
UNALLOYED MOLYBDENUM SHEET

Test Conditions

Sheet thickness = 0.040 inch
Machine = Marquardt ETTM
Strain rates = 0.001 in./in./sec to yield
0.01 in./in./sec to rupture

Hold time = 5 minutes
Temperature indicator = Shawmeter
Test atmosphere = Air

Specimen Number	Test Temperature (°F)	0.2% Yield Strength (Ksi)	Ultimate Tensile Strength (Ksi)	Elongation in 1 inch (%)	Young's Modulus (10^6 psi)
831H	2800	7.5	12.3	4.0	--
832H	2800	8.2	11.8	4.2	8.0
829H	3000	7.5	11.0	9.9	5.7
826H	3000	6.8	10.7	9.6	5.1
824H	3000	7.4	12.3	4.0	5.0
858H	3200	6.2	10.0	9.6	--
859H	3200	6.1	10.0	11.5	4.8
860H	3200	6.3	10.4	11.8	--

MAC A673

MAC A673

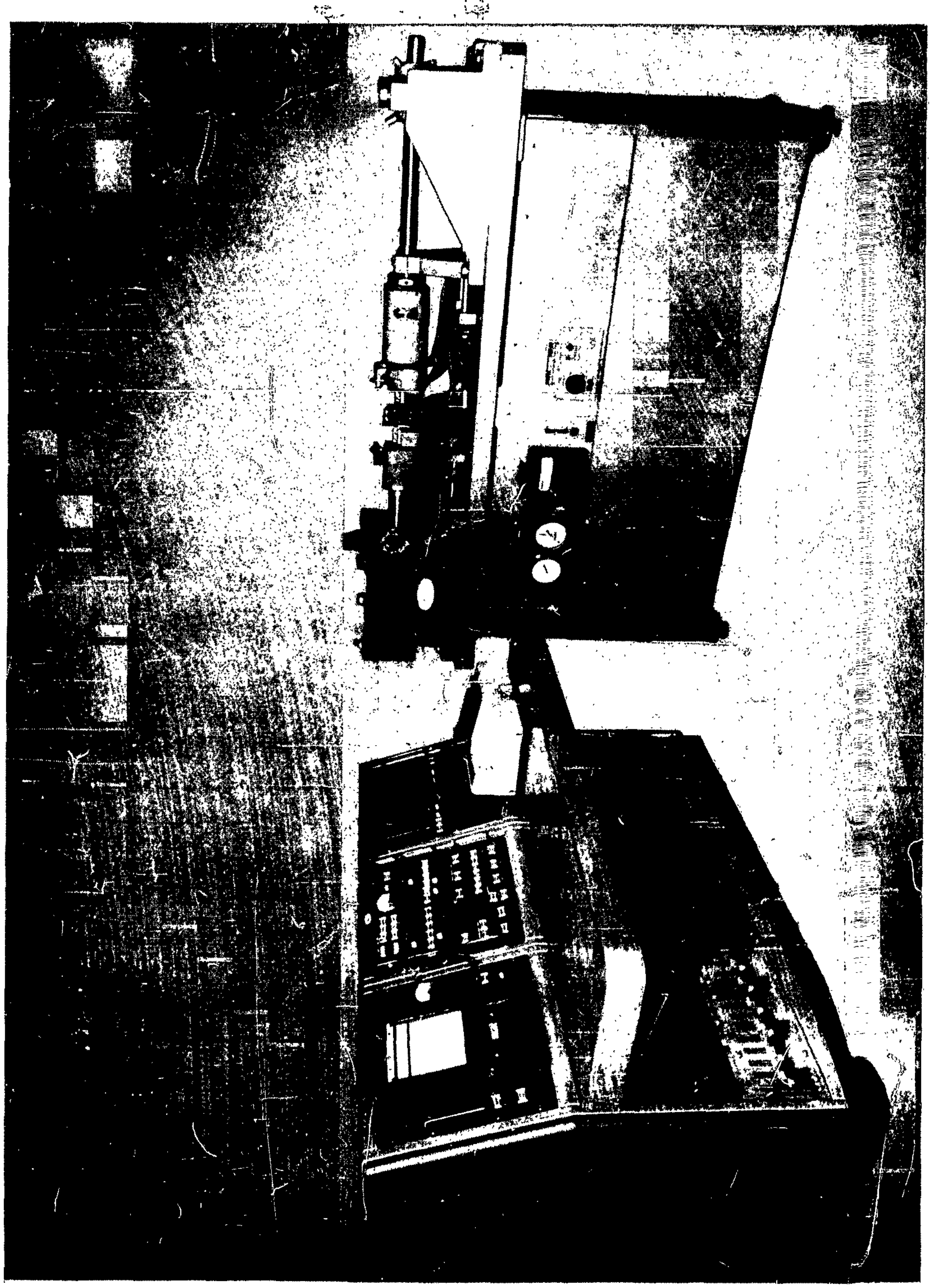
TABLE II

CREEP-RUPTURE PROPERTIES OF DISILICIDE-COATED UNALLOYED MOLYBDENUM SHEET

Test Conditions

Sheet thickness = 0.040-inch
Machine = Marquardt ETTM
Test indicator = Shawmeter
Test atmosphere = Air

Specimen Number	Test Temperature (°F)	Creep Stress (Ksi)	Time to Reach Creep Strain (seconds)						Rupture Time (seconds)	Elongation in 1 inch (%)
			0.05%	0.2%	0.5%	1.0%	2.0%	4.0%		
839H	2800	4.5	13	45	495	1,420	4,720	9,175	10,235	6.0
840H	2800	4.15	16	161	660	2,770	--	--	--	--
841H	2800	4.0	105	770	3,060	5,450	12,120	20,650	22,327	6.0
838H	2800	4.75	5	42	360	1,670	3,670	7,800	8,877	5.5
853H	3000	4.0	7	34	140	445	1,250	2,480	3,055	6.0
854H	3000	3.0	265	1,120	3,720	14,400	42,960	--	--	--
855H	3000	3.75	95	670	2,280	5,400	9,875	--	--	--
856H	3000	3.5	25	230	840	2,180	5,315	11,860	12,813	5.0
857H	3000	3.7	20	201	800	2,350	6,660	14,115	15,725	6.0
835H	3200	2.75	70	945	3,450	7,620	17,310	24,925	25,290	4.5
836H	3200	3.35	15	140	575	1,315	3,480	6,540	7,564	5.5
861H	3200	3.05	120	552	1,580	3,755	7,620	12,220	12,646	4.7

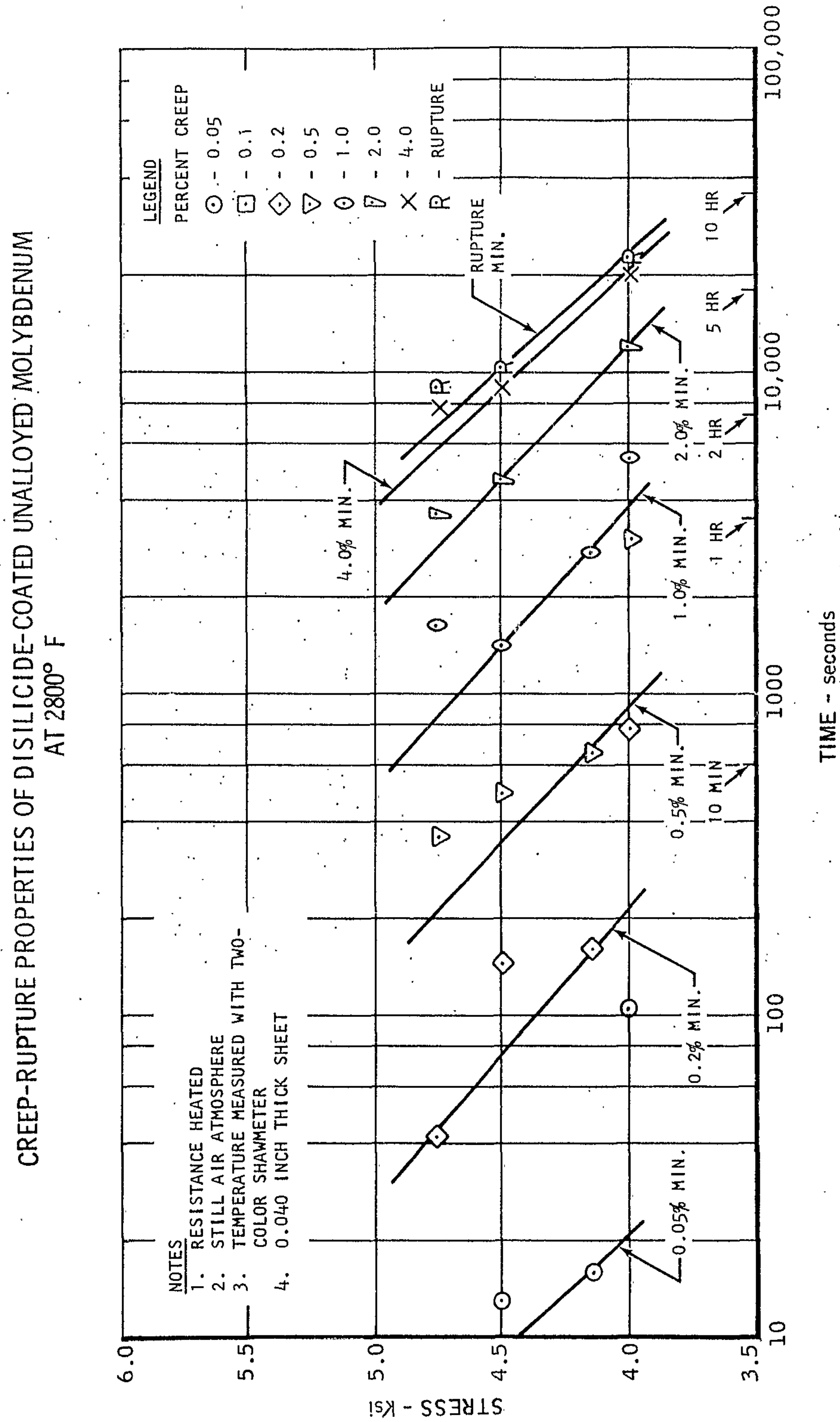


NEG. CA 2936-2

MAC A673

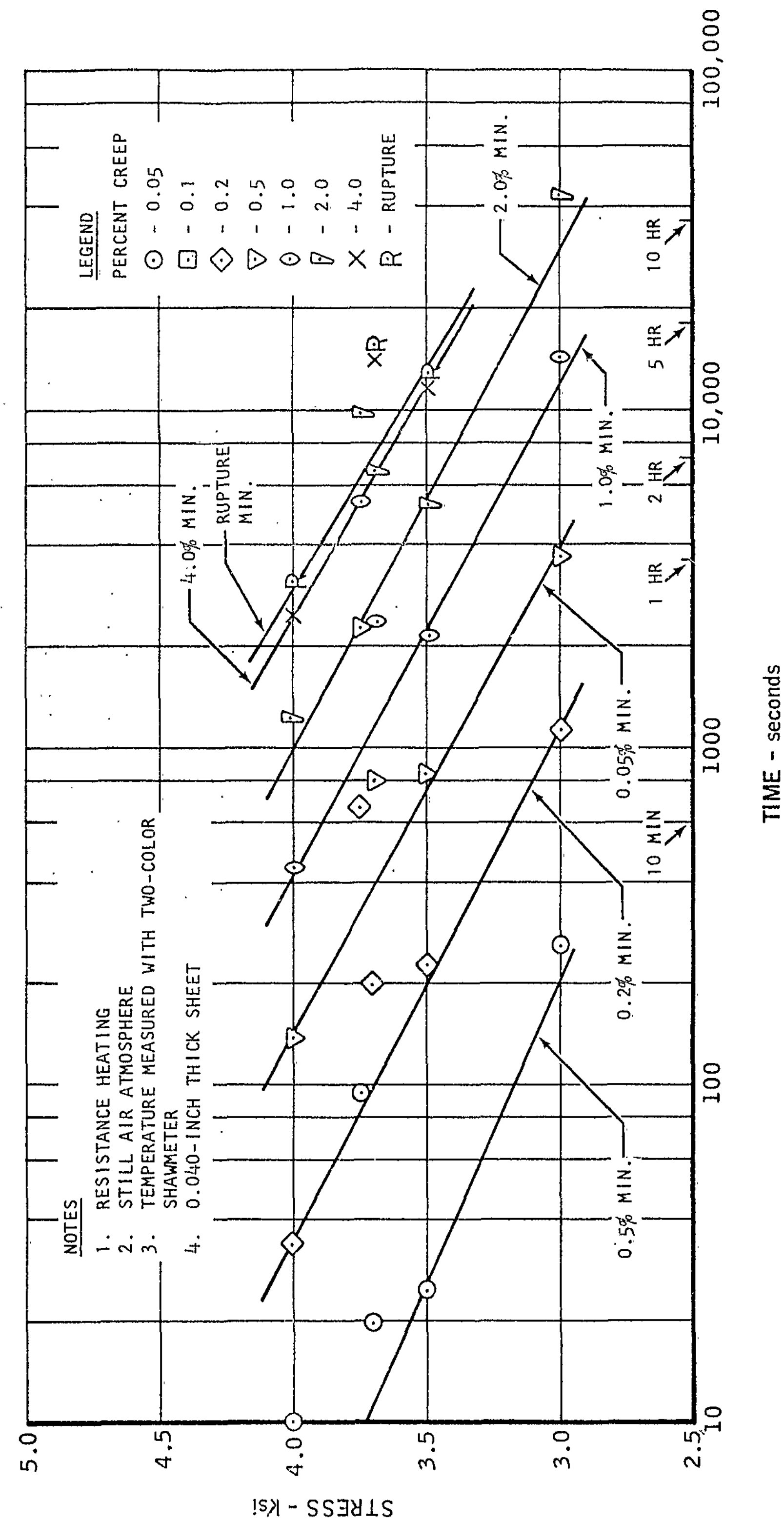
FIGURE 1

CREEP-RUPTURE PROPERTIES OF DISILICIDE-COATED UNALLOYED MOLYBDENUM AT 2800° F

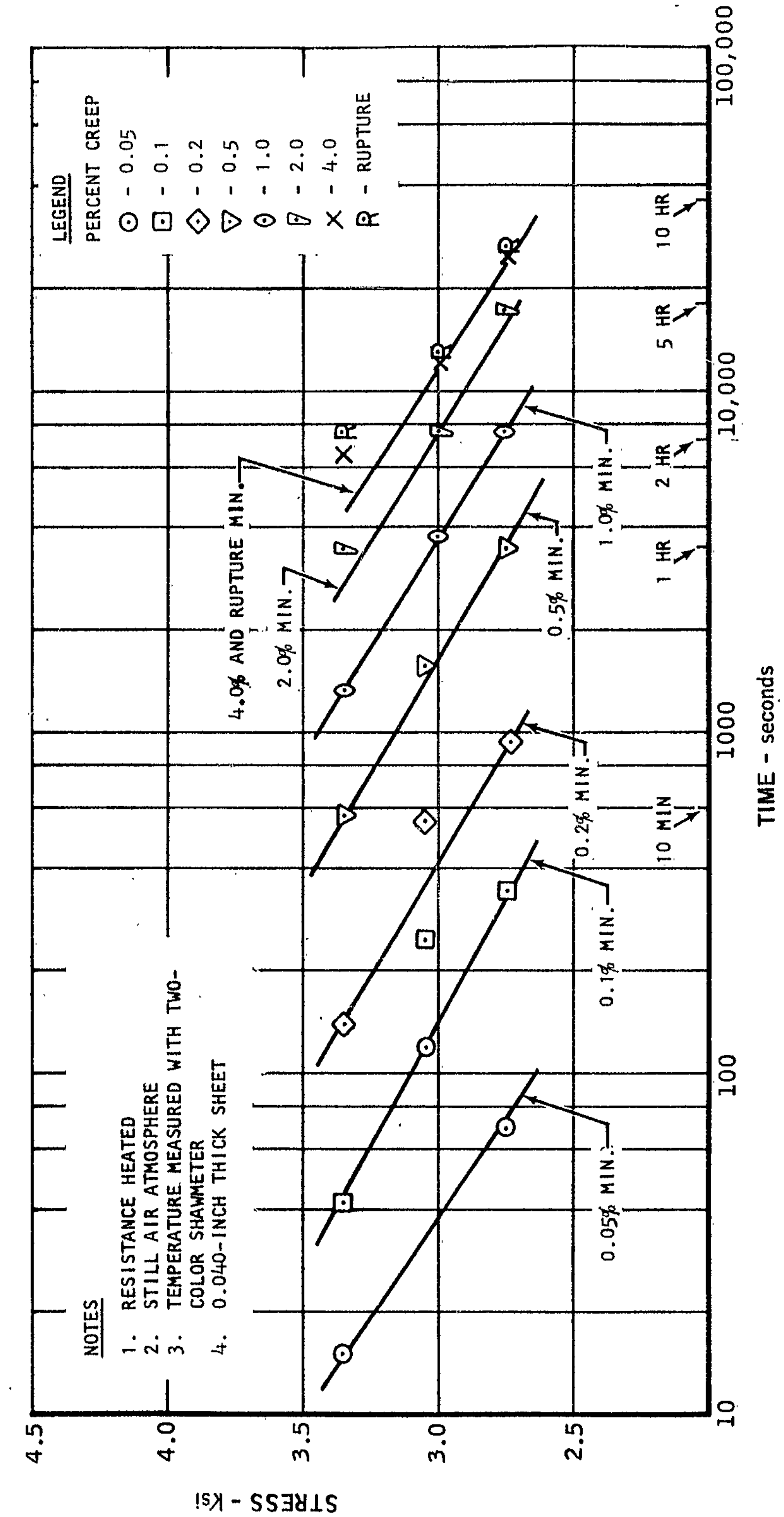


MAC A673

CREEP-RUPTURE PROPERTIES OF DISILICIDE-COATED UNALLOYED MOLYBDENUM AT 3000° F

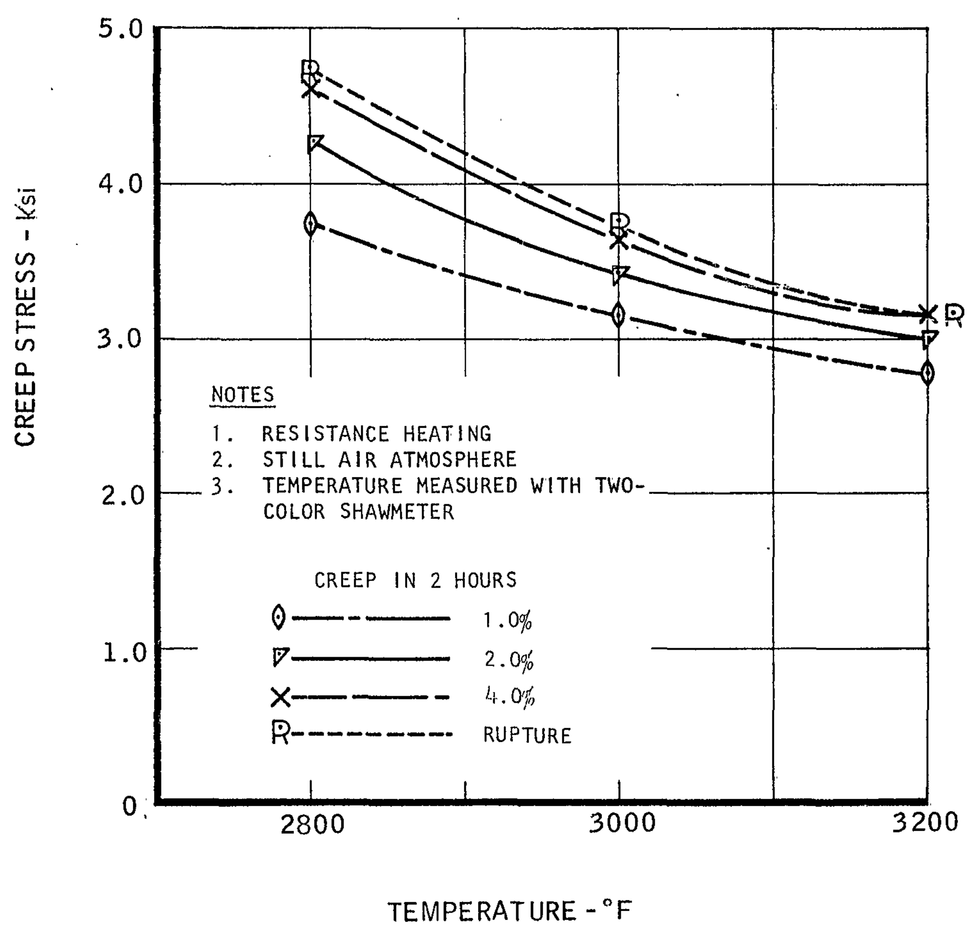


CREEP-RUPTURE PROPERTIES OF DISILICIDE-COATED UNALLOYED MOLYBDENUM
AT 3200° F



MAC A673

CREEP-RUPTURE PROPERTIES
OF DISILICIDE-COATED UNALLOYED MOLYBDENUM



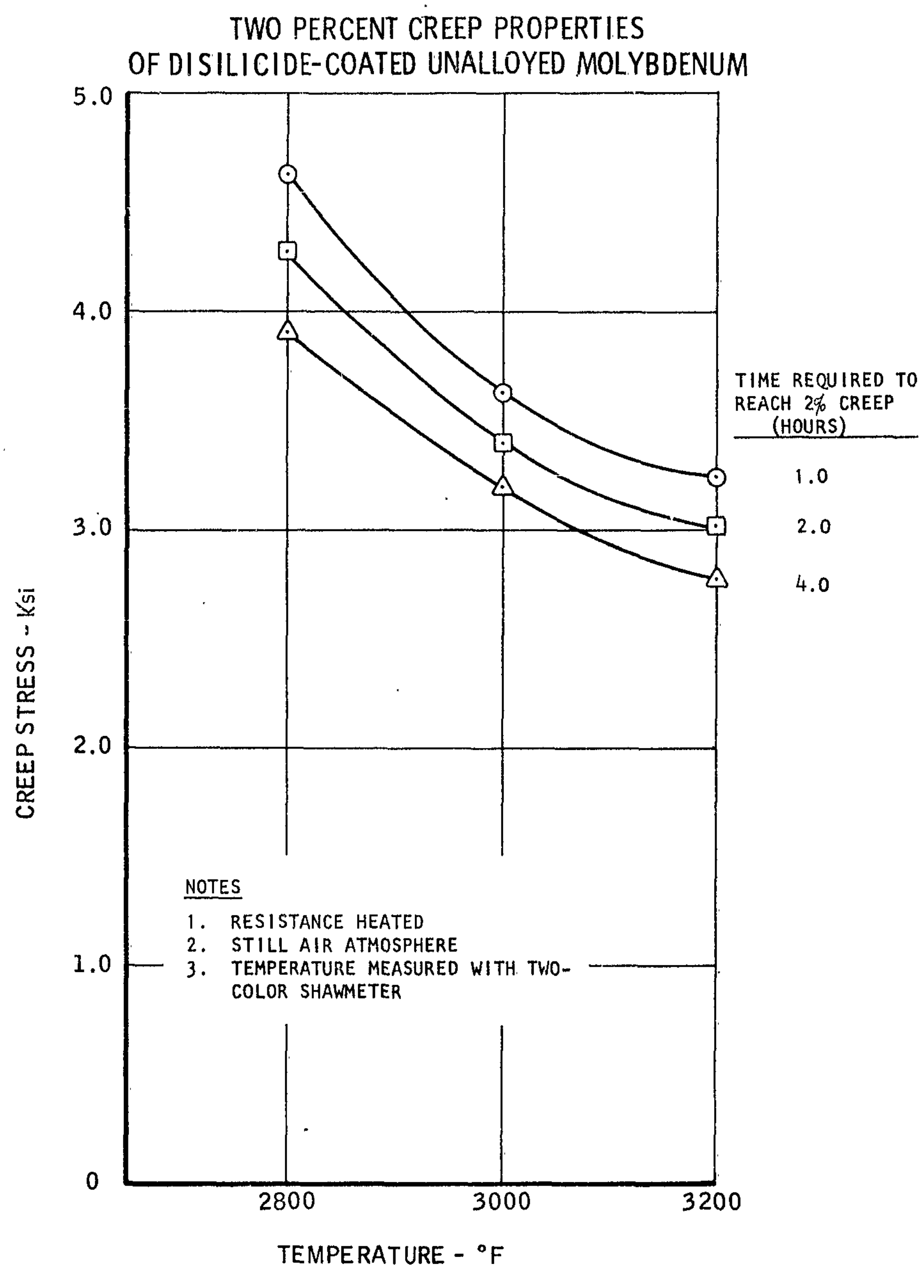

TWO PERCENT CREEP PROPERTIES
OF DISILICIDE-COATED UNALLOYED MOLYBDENUM
5.0
4.0
3.0
2.0
1.0
0
CREEP STRESS - Ksi
2800
3000
3200
TEMPERATURE - °F
TIME REQUIRED TO REACH 2% CREEP (HOURS)
1.0
2.0
4.0
NOTES
1. RESISTANCE HEATED
2. STILL AIR ATMOSPHERE
3. TEMPERATURE MEASURED WITH TWO-COLOR SHAWMETER

FIGURE 6

DISTRIBUTION

Copy No.	Transmitted to
1.	Syracuse University Research Institute Department of Chemical Eng. & Metallurgy Syracuse 10, N. Y. Attn.: Dr. Volker Weiss
2.	Syracuse University Research Institute Box 145, University Station Syracuse 10, N. Y. Attn.: Dr. C. S. Grove, Jr.
3.	Defense Metals Information Center Battelle Memorial Institute 505 King Avenue Columbus 1, Ohio
4, 5.	Commander Aeronautical Systems Division Directorate of Materials & Processes Wright-Patterson AFB, Ohio Attn.: ASRCEM-1
6.	Thermophysical Properties Research Center School of Mechanical Engineering Lafayette, Indiana Attn.: Dr. Y. S. Touloukian
7.	Plastec Picatinny Arsenal Dover, New Jersey
8.	Belfour Engineering Co. Suttons Bay, Michigan Attn.: Albert J. Belfour
9.	Hughes Aircraft Company Florence and Teale Streets Culver City, California Attn.: E. M. Wallace, Library Services
10.	Commander Aeronautical Systems Division Directorate of Materials & Processes Wright-Patterson AFB, Ohio Attn.: ASRCEE

MAC A673

DISTRIBUTION (Continued)

Copy No.	Transmitted to
11 to 20.	Armed Services Technical Information Agency Arlington Hall Station Arlington 12, Virginia Attn.: TIPA
21.	Forest Products Laboratory Madison 5, Wisconsin Attn.: Mr. Fred Werren
22.	Commander Aeronautical Systems Division Directorate of Materials and Processes Wright-Patterson AFB, Ohio Attn.: ASRCEM-1, Library